PDHonline Course C765 (8 PDH)

Sustainability for Civil Engineers

PDH Online | PDH Center

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On Capital Projects, Sustainability Objective is to Achieve the Values of a “Triple Bottom Line”

Economic:

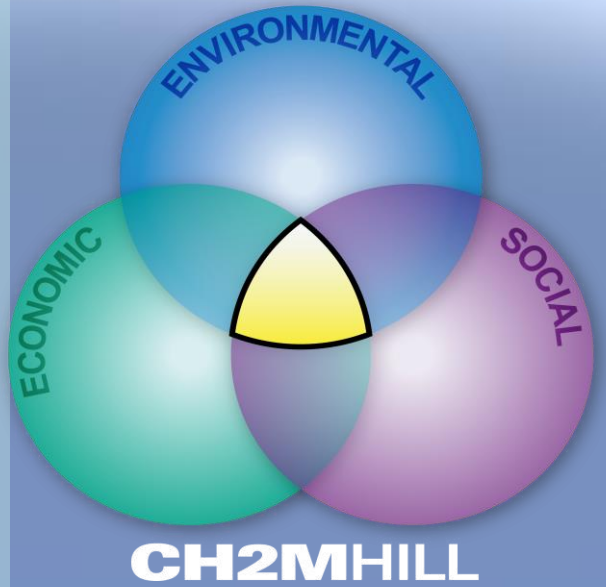
Balance financial objectives on a project life cycle basis. Good sustainability practices often result in measurable life cycle financial savings.

Social:

Address community and stakeholder values including health and safety of construction workers, clients/owners, occupants and users of facilities, and all people working on the project.

Environmental:

Reduced impact to and consumption of natural resources.



Advancing Sustainability in Design

- Integrate sustainability vision/ values into design
- Implement sustainability objectives, measurement system, systems thinking models and sustainability framework
- Implement sustainability approaches in
  - Site selection and development plan
  - Building envelope,
  - Facilities features
- Materials selection/ specification
  - Waste minimization requirements
  - Energy systems
  - Water systems
  - Ecosystems
- *The BEES (Building for Environmental and Economic Sustainability)* software developed by the NIST (National Institute of Standards and Technology) Green Buildings implements a technique for balancing the environmental and economic performance of building products.

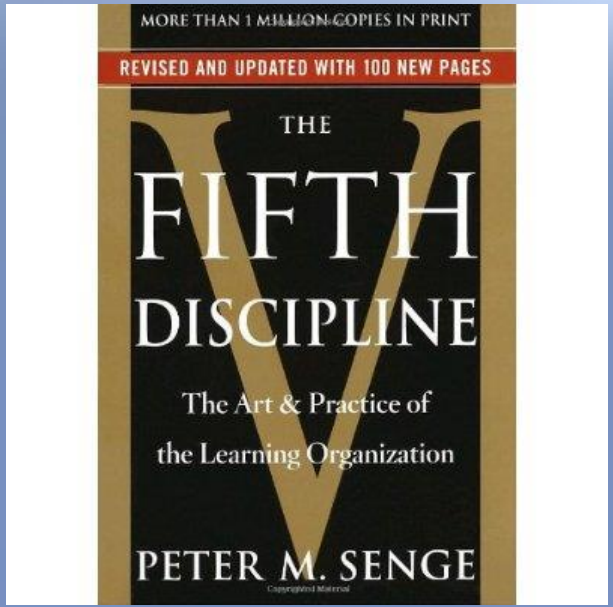
60 to 80% “of overall product costs as well as products environmental impact are determined during the design phase”
(Libra, 2007*,as cited in Sustainable Industrial Construction, CII, 2008)

Systems Thinking – breaking apart problems results in paying a hidden enormous price

opening paragraph

"From a very early age, we are taught to break apart problems, to fragment the world. This apparently makes complex tasks and subjects more manageable, but we pay a hidden, enormous price. We can no longer see the consequences of our actions: we lose our intrinsic sense of connection to a larger whole."

Peter Senge, p. 3



Sustainability Assessment Framework based on Triple Bottom Line

CH2M HILL Sustainability Assessment Framework (SAF)		
ENVIRONMENTAL	**ECONOMIC**	**SOCIAL**
Energy	Cost	Equity
Climate Change	Return on Investment	Aesthetics
Transportation/Land Management	Liabilities	Justice
Water	Assets	Health and Safety
Materials Use/Waste	Economic Development	
Biodiversity/Habitat	Life Cycle	
	Sustainable Procurement	

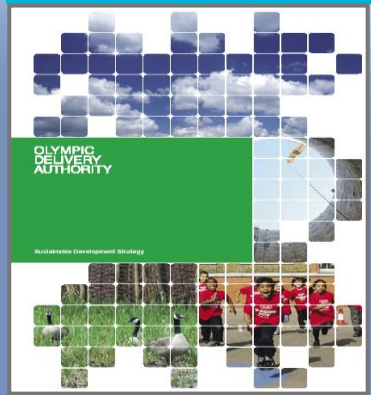
"We want London 2012 to be the first 'sustainable' Games, setting new standards for major events."

London Olympic Development Authority

- Bid commitment
- Towards a One Planet Olympics
- London 2012 Sustainability Policy

  (Climate Change, Waste, Biodiversity, Healthy Living, Inclusion)
- ODA Sustainable Development Strategy Report

  (12 themes)
- London 2012 Sustainability Plan



Sustainable Design – Informative Guidance Manuals Available

Implement in Design Practice

- Life Cycle Assessment (LCA) for sustainability features
- Evaluate Materials & Resources for Sustainability*

– Material cost
– Life cycle cost impact
– Energy efficiency
– Water efficiency
– Material reduction
– Locally manufactured

– Non-toxic
– Recycled content
– Rapidly renewable
– Locally derived raw material Certified Wood
– Salvaged

Sustainable Design Reference
SUSTAINABLE BUILDING TECHNICAL MANUAL
Green Building Design, Construction, and Operations
Produced by Public Technology Inc., US Green Building Council
Sponsored by U.S. Department of Energy & U.S. Environmental Protection Agency

*Los Alamos National Laboratory Sustainable Design Guide, 2002 (p.237)

What is Sustainability? A Buzz Word?

- **Sustainability** is the capacity to endure. For humans, sustainability is the potential for persistent well being, which depends on the well being of the natural world and the responsible use of natural resources.
- For engineers, sustainable development includes using technology to conserve natural resources (including energy) and limit emissions so that future generations will be able to enjoy equal or better quality of life.

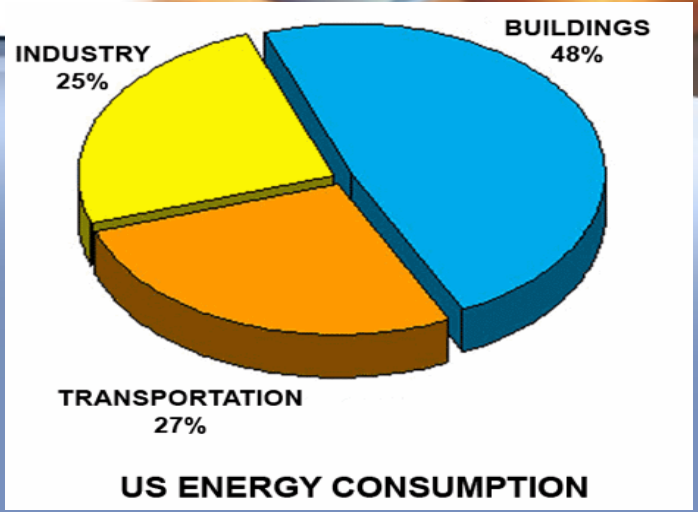
Why is Sustainability Important?

- Nexus of major issues caused by rapidly growing global economy:
  - Energy constraints
  - Global warming
  - Resource availability (metals, cement, oil etc.)
- World population is 6 billion (B) → 12 B projected by 2100. US at 0.5B by 2050.
- US and EU (combined population = 0.75 B) consume most of world resources. China catching up fast.
- Remaining 5.25 B want everything we have. Not enough to go around if we do business as usual.

Industry Design Practices: Sustainability

…in the United States, buildings account for:

- 72% of electrical consumption
- 48% of ALL energy use
- 40% of raw materials usage
- 30% of solid waste produced
- 48% of all carbon emissions



Source: Hoffman Corp.

Carbon Facts:

US = average 20 ton per person, per year

European nations = average 6 ton per person, per year

EPA / California legislation: reduce carbon emissions by 25% from 1990 levels

AIA 2030 Challenge – net zero carbon emissions by 2030

Sustainability – One Method

The 2,000 Watt World

What Level of Energy Use Would Be Sustainable?

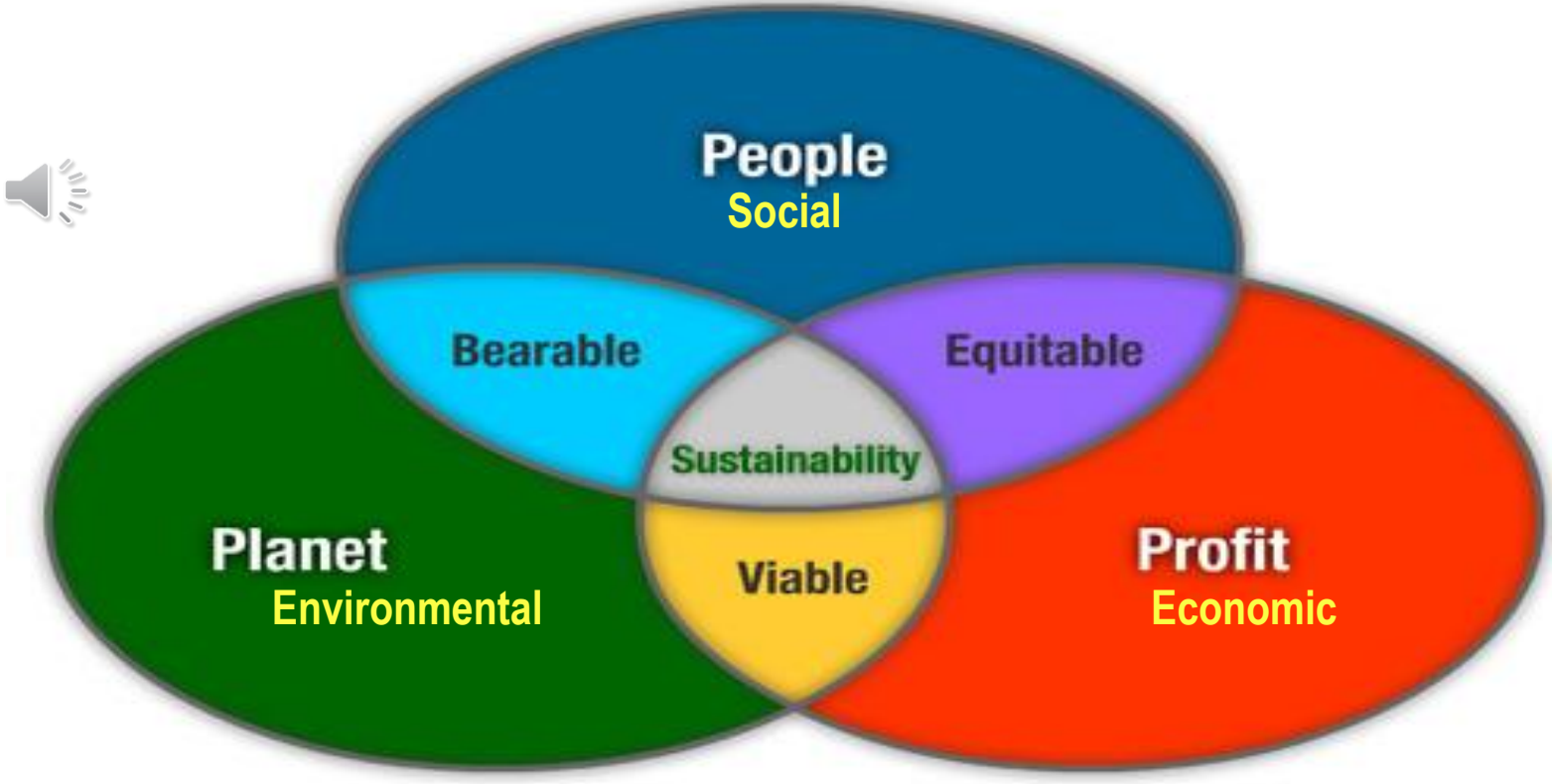
- Swiss Method = Continuously burning 20 100w bulbs (2,000w) per person
- **Bangladesh = 300w**
- **India = 1,000w**
- **China = 1,500w**
- **Switzerland = 5,000w**
- **Western EU Countries = 6,000w**
- **US and Canada = 12,000w**

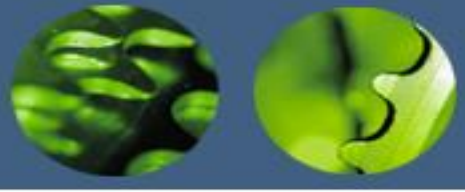
Source: Swiss Federal Institute (from *The Essential Engineer)*

Sustainability Assessment Framework based on *Triple Bottom Line*

Source: AM Consortium, Inc

Sustainability Assessment Framework based on *Triple Bottom Line – TBL or 3BL*





Sustainability Assessment Framework based on *Triple Bottom Line*

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Energy	Cost	Equity
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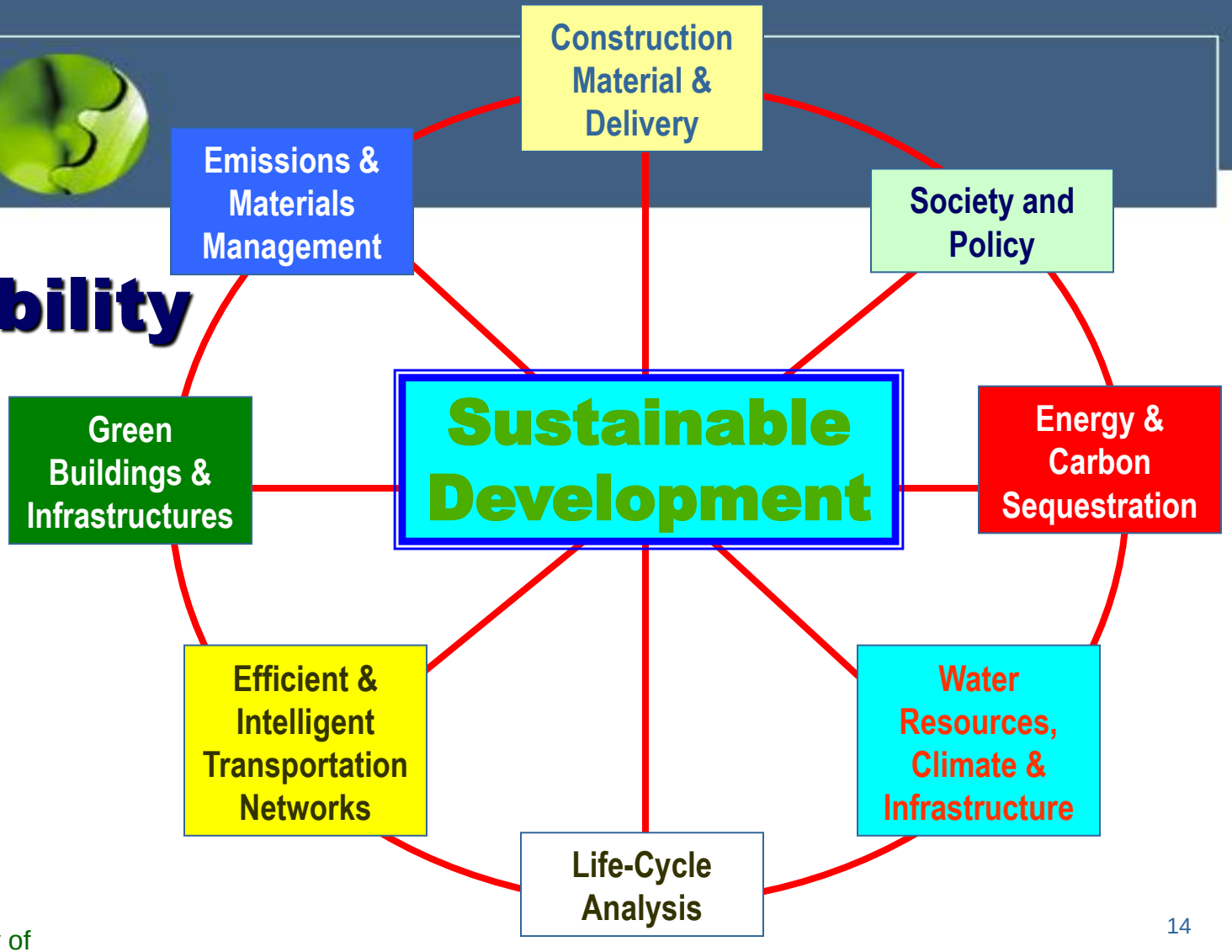
Materials Use/Waste	Economic Development	
Biodiversity/Habitat	Life Cycle	
	Sustainable Procurement	

Source: CH2MHILL

Sustainability Wheel



Source: University of Wisconsin-Madison

Robert K. Merton listed five possible **causes of unintended consequences**:

- ***Ignorance*** (It is impossible to anticipate everything, thereby leading to incomplete analysis)
- ***Error*** (Incorrect analysis of the problem or following habits that worked in the past but may not apply to the current situation)
- ***Immediate interest***, which may override long-term interests
- ***Basic values*** may require or prohibit certain actions even if the long-term result might be unfavorable (these long-term consequences may eventually cause changes in basic values)
- ***Self-defeating prophecy*** (Fear of some consequence drives people to find solutions before the problem occurs, thus, the non-occurrence of the problem is unanticipated.)

- **Food for Energy (ethanol)**
- **“Tax the Rich”**
- **Don’t Cut Down Any Trees or Hunt Animals**
- **Electric Cars**
- **Others?**

Unintended Consequences

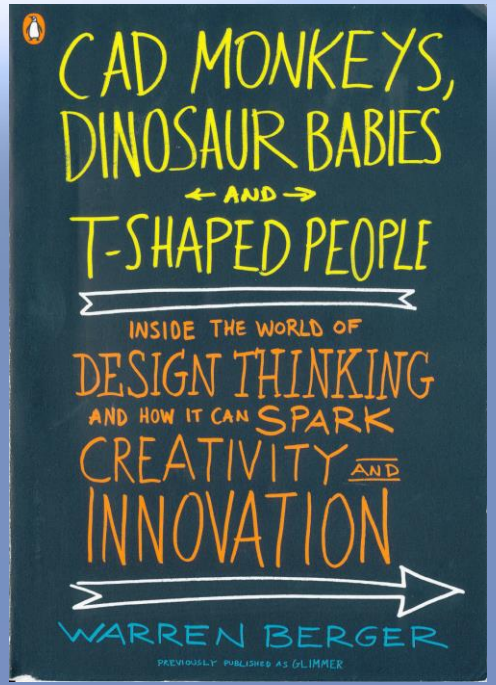
Advancing Sustainability in Planning

3 R's of Sustainability

- Reduce
- Reuse
- Recycle

- **Set a Vision**
- **Set Goals & Objectives**
  - **Apply Applicable Existing Sustainability Frameworks** from leading organizations – e.g. LEED (USGBC) green building rating system, Sustainable Sites, CEEQUAL, BREEAM, One Planet Living
  - **Develop a Tailored Sustainability Framework** - Use fundamental sustainability principles paired with your project's unique characteristics and potential impacts to achieve the greatest triple bottom line benefits (environmental, financial, and social)
- **Establish Measurement System** – criteria, methodology and implementation
- **Implement Systems Thinking Approach**

“Now that we can do anything, what will we do?” Bruce Mau, Massive Change



- “To eliminate the concept of waste means to design things - products, packaging, systems – from the very beginning in the understanding that waste does not exist.”…”
- “Does it have verse logistics? Do you have a way to get it back to the soil or back to industry?”
- “…carper maker Shaw Industries to create cradle-to-cradle carpeting.”
- “...the challenge of “designing for forever”…”
- Bruce Mau’s “Massive Change Manifesto”.

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Implement in Design Practice

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  - Material cost
  - Life cycle cost impact
  - Energy efficiency
  - Water efficiency
  - Material reduction
  - Locally manufactured
  - Non-toxic
  - Recycled content
  - Rapidly renewable
  - Locally derived raw material Certified Wood
  - Salvaged

*Los Alamos National Laboratory Sustainable Design Guide, 2002 (p.237)

What Is Sustainable Procurement*?

An organization uses its buying power to obtain from the market sustainable goods & services

- Economic: best value for money, price, quality, availability, functionality
- Environment: impacts on environment that the produce and/or service has over its whole life-cycle, from cradle to grave or cradle to cradle
- Social: effects of purchasing decisions on issues such as poverty eradication, international equity in the distribution of resources, labor conditions, human rights

*Paraphrased from United Nations Global Marketplace

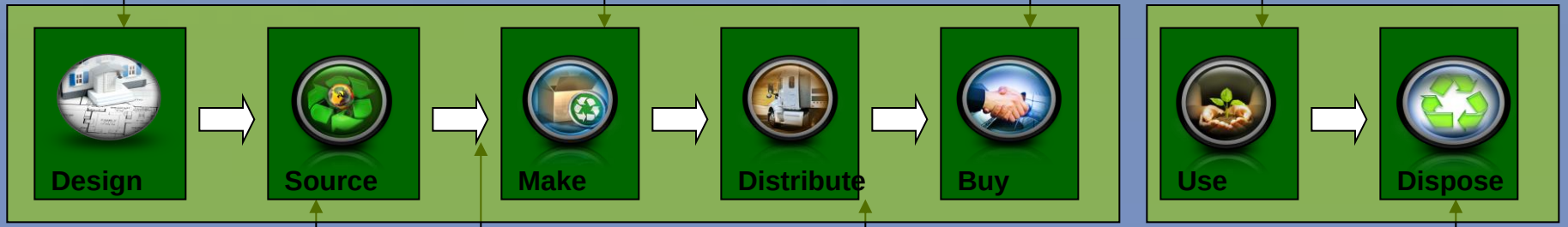
Engaging throughout the supply chain is vital to Implement Sustainable Procurement

Significant product cost and environmental impact is locked in at design phase (e.g. specification)

Manufacturing waste is both an environmental and business cost (e.g. materials efficiency)

Purchasing with sustainability in mind (e.g. green branding)

Product efficiency and durability influence environmental impacts (e.g. water efficiency)



The sustainability of sources influences overall sustainability (e.g. supplier standards, material inputs)

Energy sources and efficiency of production impact both cost and greenhouse gas emissions (e.g. demand management)

Transportation is a common contributor to greenhouse gas emissions (e.g. vehicle efficiency, network optimization)

Materials selection and assembly influence end-of-life disposal options (e.g. recyclability, take-back opportunities)

Advancing Sustainability in Procurement

- Integrate sustainability vision/ values into procurement
- Implement sustainability objectives, measurement system, systems thinking models and sustainability framework
- Commit to Green Purchasing Policy
- Implement sustainability approaches in/ with
  - Procurement planning efforts
  - Early engagement and education of supply chain
  - Supplier & subcontractor qualification systems - assess sustainability in all phases of suppliers process including sourcing, transport, manufacturing/ fabrication, resources, people, facilities, packaging, delivery and recovery/reuse
  - Life cycle assessment of suppliers materials & equipment, require supplier to include reuse or recycle costs
  - Post Award monitoring for compliance with sustainability requirements and to search for potential additional opportunities
  - Report actuals to plans

Implementing Sustainability Practices in Construction

- Integrate sustainability vision/ values into construction
- Implement sustainability objectives, measurement system, and sustainability framework
- Implement sustainability approaches in
  - Logistics
  - Site Management
  - Equipment
  - Materials selection/ specification
  - Work Methods
  - Waste minimization
  - Energy systems
  - Water systems
  - Environmental Management
  - Commissioning

Sustainable Construction Practices – Many Informative Sources Available

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	Sustainable Procurement	

Implement in Construction Practice

- Significant Opportunity to Implement Sustainable Practices in Construction
- Up-date Sustainability Assessment Framework for Construction Practices and Opportunities
- Adopt Construction Industrial Sustainability Metric (SIM)*
- Measure Capital Project performance and submit to Global Reporting Index
- Achieve ISO 14000 certification **-** for environmental management systems, audits, performance evaluation, labeling and product standards, and life-cycle assessment.
- Individual Behaviors, Individual Ownership – provide training and provide recognition & reward to individuals and team

Sustainable Construction References

Sustainable Industrial Construction
CII Research Report 250-11
September, 2008
Dr. J. K. Yates, North Dakota State Univ.

Field Guide for Sustainable Construction
Partnership for Achieving Construction Excellence
Pennsylvania State University
Pentagon Renovation and Construction Program Office
June 2004

*** from Sustainable Industrial Construction,** CII Research Report 250-11, September, 2008

Example: London 2012 Olympics – Sustainable Site Remediation and Development

Over 90% of materials/soil on the Olympic site cleaned/recovered for use

Materials approx. 2.5 M m3

- Demolition 0.5 M m3
- Excavated Soil 1.8 M m3)
- Tunnelling spoil 0.2 M m3)

Beneficial & optimal reuse strategies

- General fill approx. 50%
- Separation layer approx. 50% - base coarse, sub-base & selected engineering fill

Park View Looking West – Mid 2008

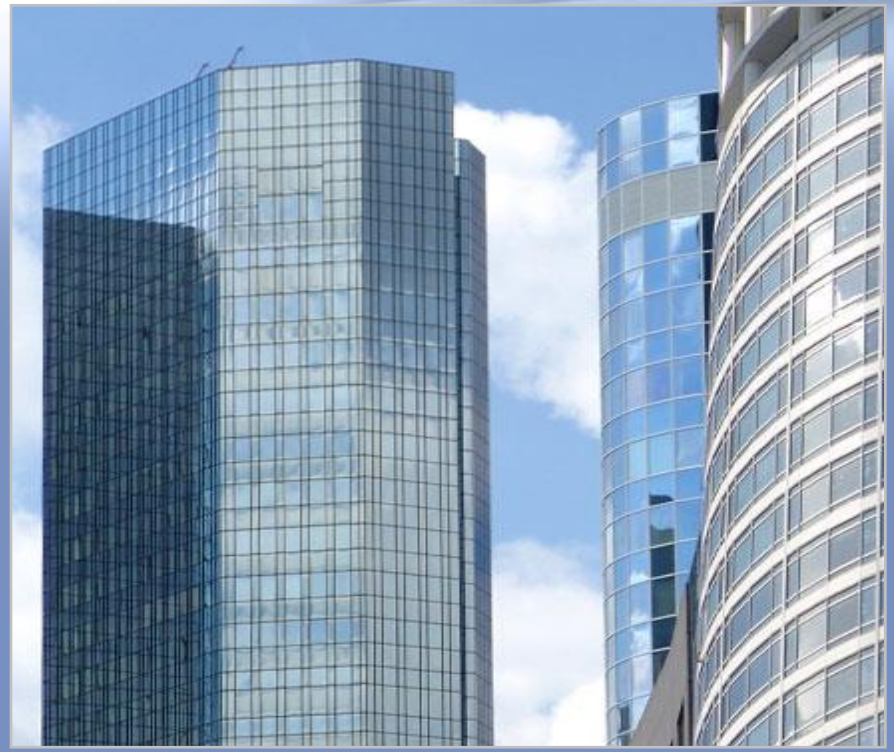
Implementing Sustainable Practices in Operations & Maintenance

- Integrate sustainability vision/ values into O&M
- Implement sustainability objectives and measurement system,
- Start early in planning & design to provide O&M input to project development
- Implement sustainability approaches in
  - Environmental Compliance
  - Alternate Materials
  - Energy Management & Minimization
  - Waste Management & Minimization
  - Water Management & Minimization
- Individual Behaviors, Individual Ownership
  - It is about people taking individual action
  - Provide training for Sustainability from the many references & sources
  - Provide recognition and award for sustainability to individuals and team

"… BioRegional uses significantly less energy than the Energy Saving Trust's best practice target. …partly due to the design of BedZED….also …BioRegional employees are more aware of their ecological impact and, for example, are more likely to turn lights and computer screens off when not in use…"

From BioRegional Web Site

Construction and operations of buildings



Buildings consume

- 12% of the potable water
- 25% of harvested wood
- 30% of the raw materials
- 39% of all primary energy
- 70% of all U.S. electricity

Source: USGBC (Figures for USA)

Life Cycle

Advancing Sustainability Throughout The Project Life-Cycle

- Establish Sustainability Objectives and Measurements
- Implement Systems Thinking Approach

- Implement Sustainability Objectives throughout the Supply Chain
- Evaluate alternative suppliers & materials
- Education suppliers and contractors on requirements

- Implement Sustainability Practices in O&M
- Environmental Compliance, Alternate Materials
- Manage energy, waste and water
-- Individual Behaviors

- Integration of Sustainability Values into design
- Implement Sustainability Approaches in Site, Building Envelope, Facilities, Materials, Energy, Water, and Life Cycle

- Implement Sustainability Practices in logistics, site management, equipment, materials, and methods
- Construction waste recycling
- Endorse Commissioning

Lifecycle Analysis

Lifecycle Stages

- **MAKE** (plan, design, construct, develop)
- **USE** (operate and maintain)
- **RENEW** (remodel, disassemble, demo)

At Each Stage of the lifecycle, focus on 4 aspects of environmental impacts

There are many other types of impacts

- **ENERGY and EMISSIONS**
- **CHEMICALS, MATERIALS, AND WASTE**
- **WATER and NATURAL RESOURCES**
- **COST, BENEFITS, and REPLACEMENT**

Source: Citizen Engineer, 2010, and F. Sherkow

Frank's Taxi Meter

- Assume that all infrastructure has a "taxi meter" running on it
- Money is needed for repairs and maintenance as soon as it is built
- The longer you wait, the higher the "bill"
- At some point, the rate of increase in this "bill" increases faster

Source: Frank Sherkow, P.E., F.ASCE

Lifecycle Analysis

	ENERGY and EMISSIONS	CHEMICALS, MATERIALS, AND WASTE	WATER and NATURAL RESOURCES	COST, BENEFITS, and REPLACEMENT
MAKE				
USE				
RENEW				

Additional Lifecycle Considerations: Supply Chain, Consumables, Hidden Impacts, Services, and Design

When to Stop Assessing

1. Be able to communicate the biggest impacts and their size
2. Sufficient data to meet any legal claims you're required to make
3. Be able to use your model to understand the size of the impacts and a result of design changes

Source: Citizen Engineer, 2010

Role of the Engineer in Sustainable Development

http://www.asce.org/Public-Policies-and-Priorities/Public-Policy-Statements/Policy-Statement-418---The-Role-of-the-Civil-Engineer-in-Sustainable-Development/

- The American Society of Civil Engineers (ASCE) defines sustainability as a set of economic, environmental and social conditions in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely, without degrading the quantity, quality or the availability of natural resources and ecosystems.
- Moreover, sustainable development is the process of converting natural resources into products and services that are more profitable, productive, and useful, while maintaining or enhancing the quantity, quality, availability and productivity of the remaining natural resource base and the ecological systems on which they depend.

- The civil engineering profession recognizes the reality of limited natural resources, the desire for sustainable practices (including life-cycle analysis and sustainable design techniques), and the need for social equity in the consumption of resources. To achieve these objectives, ASCE supports the following implementation strategies:

- Promote broad understanding of economic, environmental, political, social, and technical issues and processes as related to sustainable development;
- Advance the skills, knowledge and information necessary for a sustainable future; including habitats, natural systems, system flows, and the effects of all phases of the life cycle of projects on the ecosystem;
- Advocate economic approaches that recognize natural resources and our environment as capital assets;

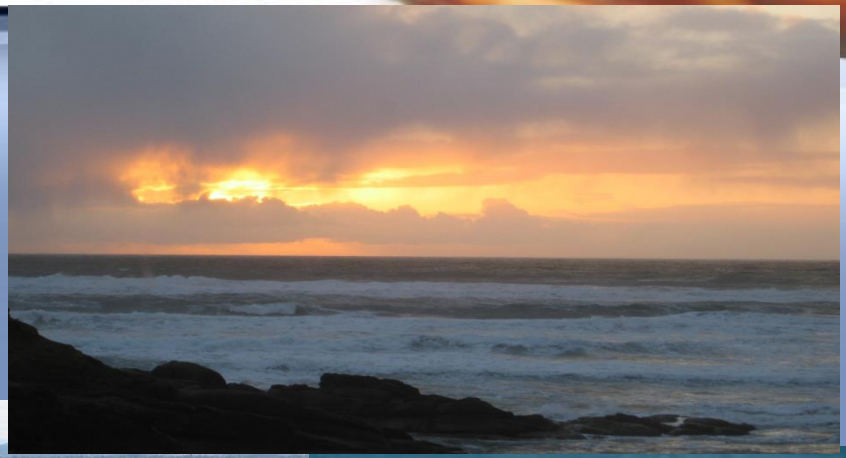
- Promote multidisciplinary, whole system, integrated and multi-objective goals in all phases of project planning, design, construction, operations, and decommissioning;
- Promote reduction of vulnerability to natural, accidental, and willful hazards to be part of sustainable development; and
- Promote performance based standards and guidelines as bases for voluntary actions and for regulations in sustainable development for new and existing infrastructure.

Rationale

- Engineers have a leading role in planning, designing, building and ensuring a sustainable future. Engineers provide the bridge between science and society. In this role, engineers must actively promote and participate in multidisciplinary teams with other professionals, such as ecologists, economists, and sociologists to effectively address the issues and challenges of sustainable development.
- *ASCE Policy Statement 418*
  First Approved in 1993
- Approved by the Committee for Sustainability on April 9, 2010
  Approved by the Policy Review Committee May 7, 2010
  Adopted by the Board of Direction on July 10, 2010

Your Responsibility

- You are a steward of the **Built Environment**
- You are a steward of the **Entire Environment**
- You shall hold paramount the **Safety, Health and Welfare of the Public**



Engineering Is Changing Rapidly

- The complexity of the design space is increasing:
  - Materials
  - Processes
  - Information Technology
  - Engineered Systems
- The complexity of the constraint set has increased
- The role of engineers in industry and government has expanded
- Globalization is introducing major changes in the engineering profession

Citizen Engineer

Source: Citizen Engineer, 2010

What is a Citizen Engineer?

- We are the connection points between science and society . . . between pure knowledge and how to use it.

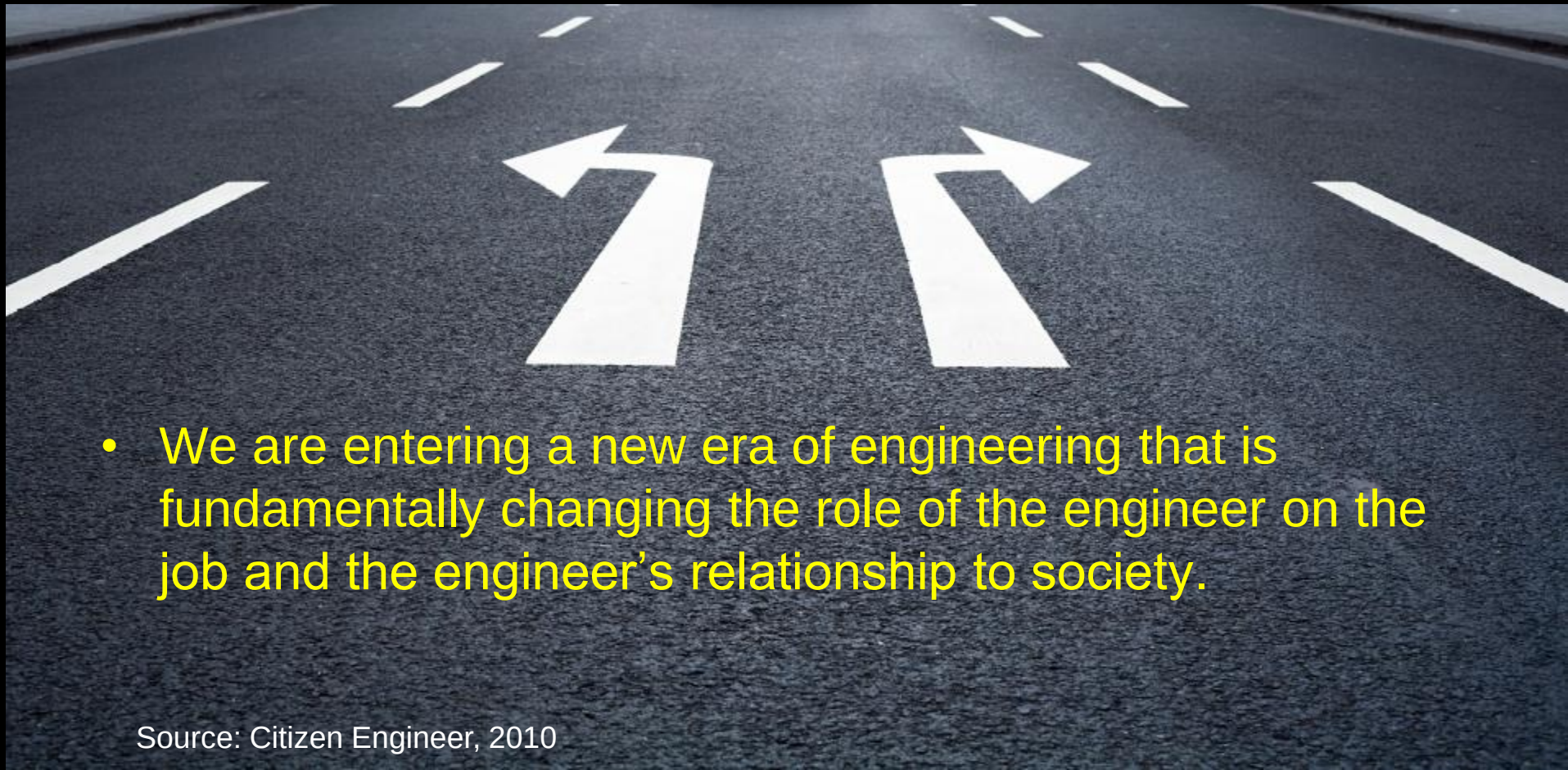
Citizen Engineers are . . .

- Techno-responsible,
- Environmentally responsible,
- Economically responsible, and
- Socially responsible

. . . participates in the engineering community

Source: Citizen Engineer, 2010

Citizen Engineer



- We are entering a new era of engineering that is fundamentally changing the role of the engineer on the job and the engineer's relationship to society.

Source: Citizen Engineer, 2010

- **How will new era change the way your company or agency innovates?**

Source: Citizen Engineer, 2010 Photo: China Maglev Station

- **How will it impact the way engineers collaborate – with each other, across the organization, between organizations?**

Source: Citizen Engineer, 2010

- **How can engineers help society better understand the technologies, products, and projects that they create and work with?**

Source: Citizen Engineer, 2010

- **Should engineers become more influential and participate in public policy?**

Source: Citizen Engineer, 2010

- **Should engineers play a larger role in educating and shaping the public's view of technology and its implications?**

Source: Citizen Engineer, 2010

Your Planet Needs

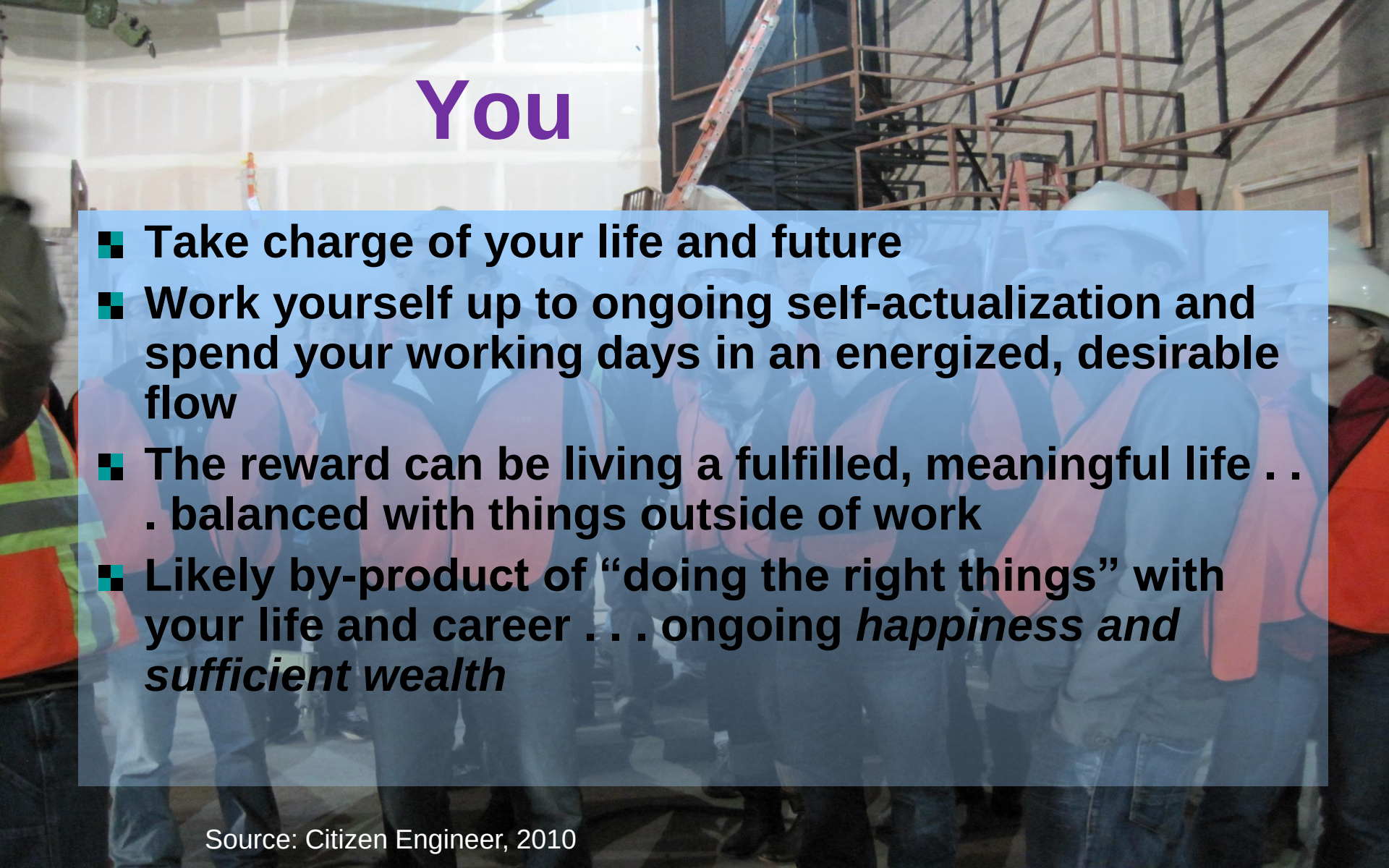
- ✓ Sustainable energy and environmental solutions
- ✓ Protection of local, regional and global environmental systems
- ✓ Agricultural technology with food distribution systems
- ✓ Advanced bio-medical technology
- ✓ New energy- and environmentally efficient transportation systems
- ✓ Ever-advanced computer and communications systems
- ✓ Advanced structures – buildings, bridges, highways and railroads
- ✓ Improved water systems

Source: Citizen Engineer, 2010 and F. Sherkow

Your Country Needs

- **Leaders in global imperatives**
- **Strong technical industrial base – *makes and exports products***
- **Technically educated workforce**
- **Security – economic, military, and social**

Source: Citizen Engineer, 2010



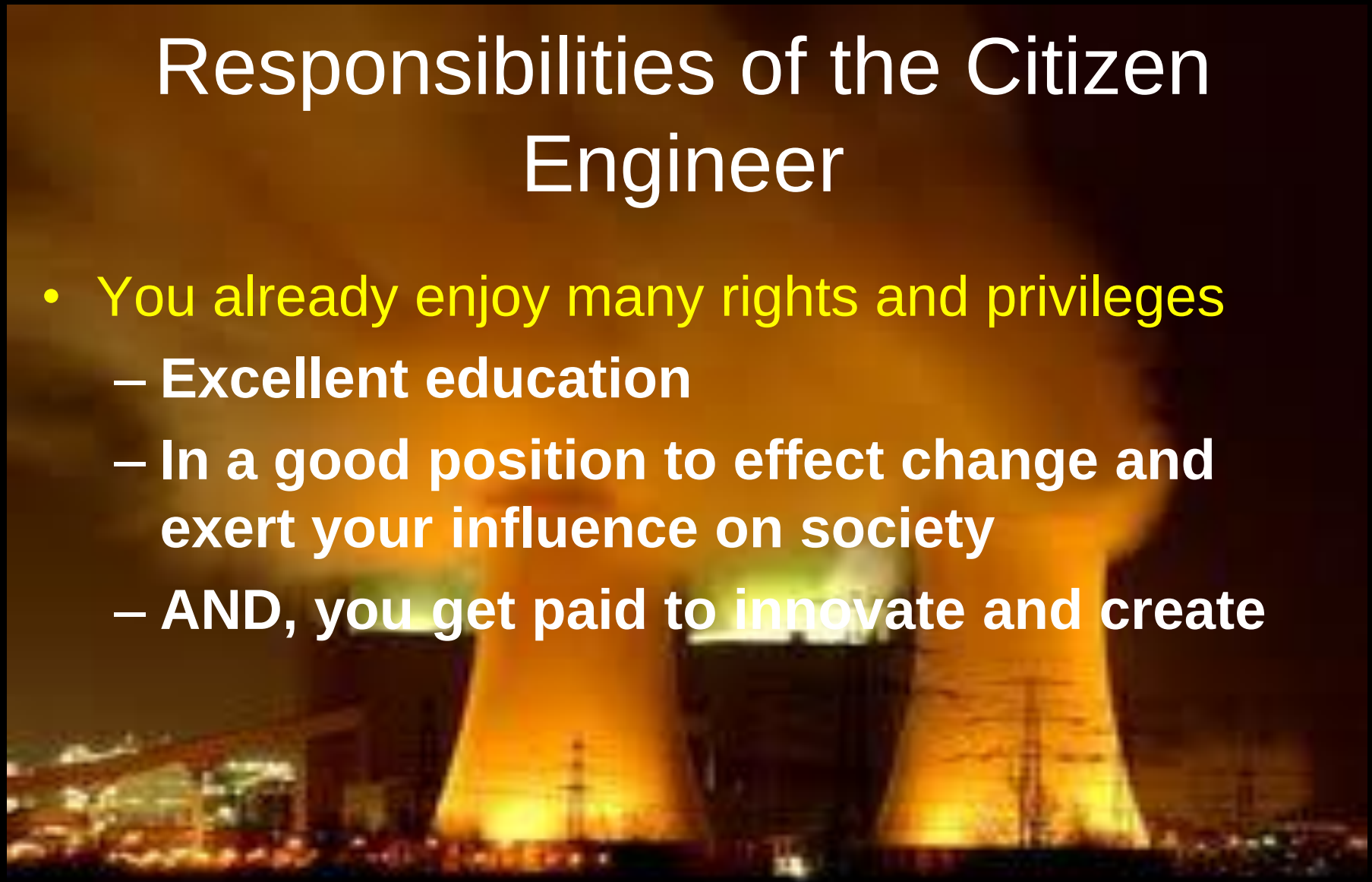
You

- **Take charge of your life and future**
- **Work yourself up to ongoing self-actualization and spend your working days in an energized, desirable flow**
- **The reward can be living a fulfilled, meaningful life . . . balanced with things outside of work**
- **Likely by-product of "doing the right things" with your life and career . . . ongoing *happiness and sufficient wealth***

Source: Citizen Engineer, 2010

Responsibilities of the Citizen Engineer

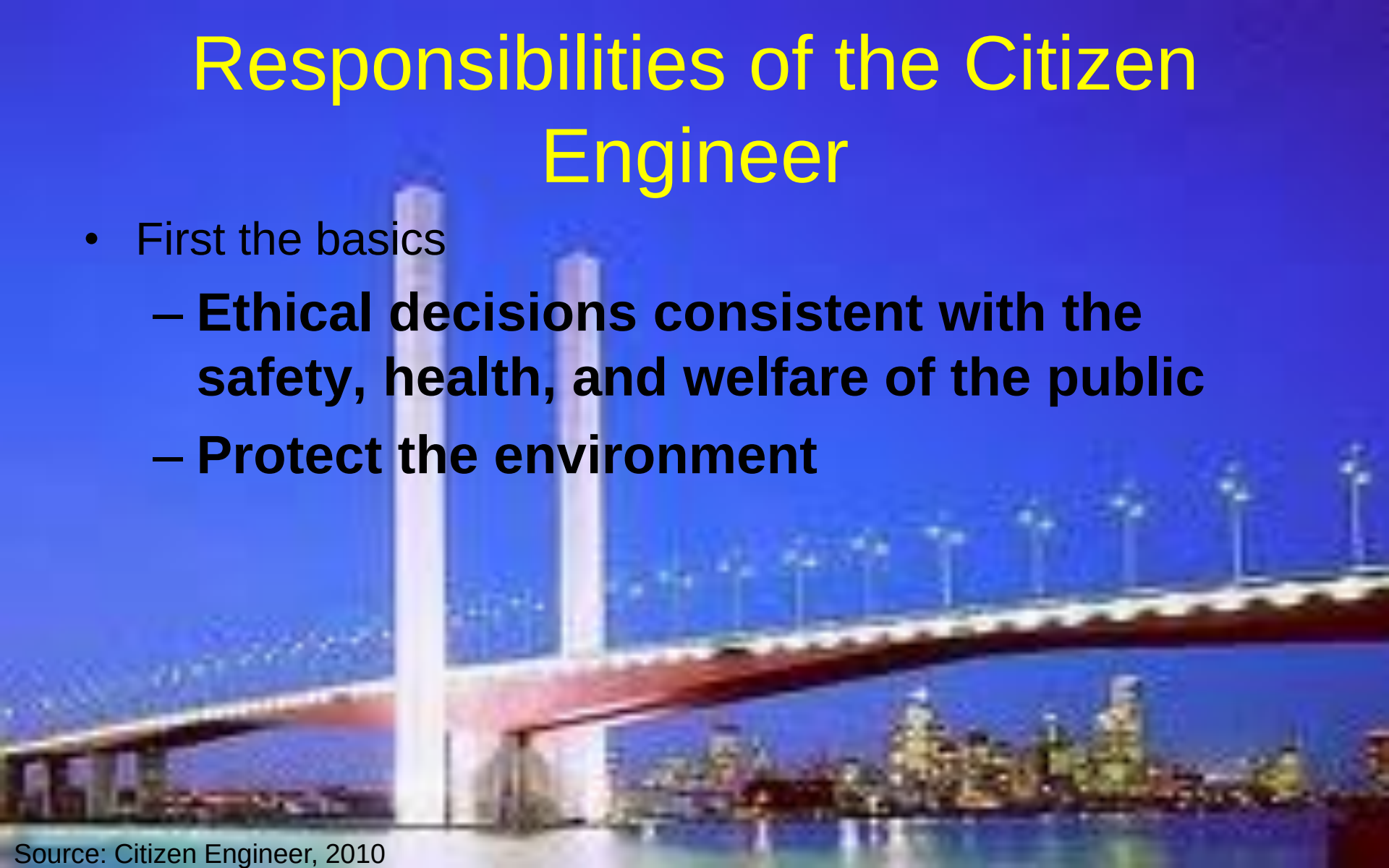
- You already enjoy many rights and privileges
  - **Excellent education**
  - **In a good position to effect change and exert your influence on society**
  - **AND, you get paid to innovate and create**



Source: Citizen Engineer, 2010

Responsibilities of the Citizen Engineer

- First the basics
  - **Ethical decisions consistent with the safety, health, and welfare of the public**
  - **Protect the environment**



Source: Citizen Engineer, 2010

Responsibilities of the Citizen Engineer

- Go beyond . . .
  - Stay abreast of the issues
  - Help educate others who may impact engineering, infrastructure, environment and society
  - Embrace new forms of responsibility that are becoming important to all of us

1. **Environmental responsible**
2. **Techno responsible**
3. **Customer/stakeholder responsible**

Source: Citizen Engineer, 2010

Environmental Responsibility

- Determine the **carbon footprint** of your project *(development, operations, demo)*
- Understand the impact of different **sources of electricity and power**
- Know which **chemicals and materials** are desirable and which to avoid
- Maximize **recyclability** and minimize **waste**
- Determine the **fresh water footprint** of your project *(development, operations, demo)*

Source: Citizen Engineer, 2010

Aggressive Initiatives

1. **Eliminate Waste** – All forms in every area of design, development, operations, and renewal

Source: Citizen Engineer, 2010

Aggressive Initiatives

2. **Benign Emissions** – Eliminate toxic substances from products, vehicles, and facilities

Source: Citizen Engineer, 2010

Aggressive Initiatives

3. **Renewal Energy** – Build and operate facilities with renewable energy sources: solar, wind, landfill gas, biomass, geothermal, tidal/wave, hydro, hydrogen, and non-petroleum-based

Source: Citizen Engineer, 2010

Aggressive Initiatives

4. **Close the Loop** – Redesign processes and facilities to close the technical loop using recovered and bio-based material

Source: Citizen Engineer, 2010

Aggressive Initiatives

5. **Resource-efficient Transportation –** Transporting people and goods efficiently to reduce waste and emissions

Source: Citizen Engineer, 2010

Aggressive Initiatives

Source: Citizen Engineer, 2010

6. **Sensitizing Stakeholders** – Create a culture that integrates sustainability principles and improves people's lives and livelihoods

Aggressive Initiatives

7. **Redesigning Commerce** – Create new business model that supports the value of sustainability-based commerce

Source: Citizen Engineer, 2010

Education of the Citizen Engineer

Source: Citizen Engineer, 2010

- **Learn** – relationships between what you do and the broader society interests of environment, safety and trust, security and privacy, choice and competition

- **Understand the laws and public policy** – What's your level of understanding about the legal and political system?

Source: Citizen Engineer, 2010

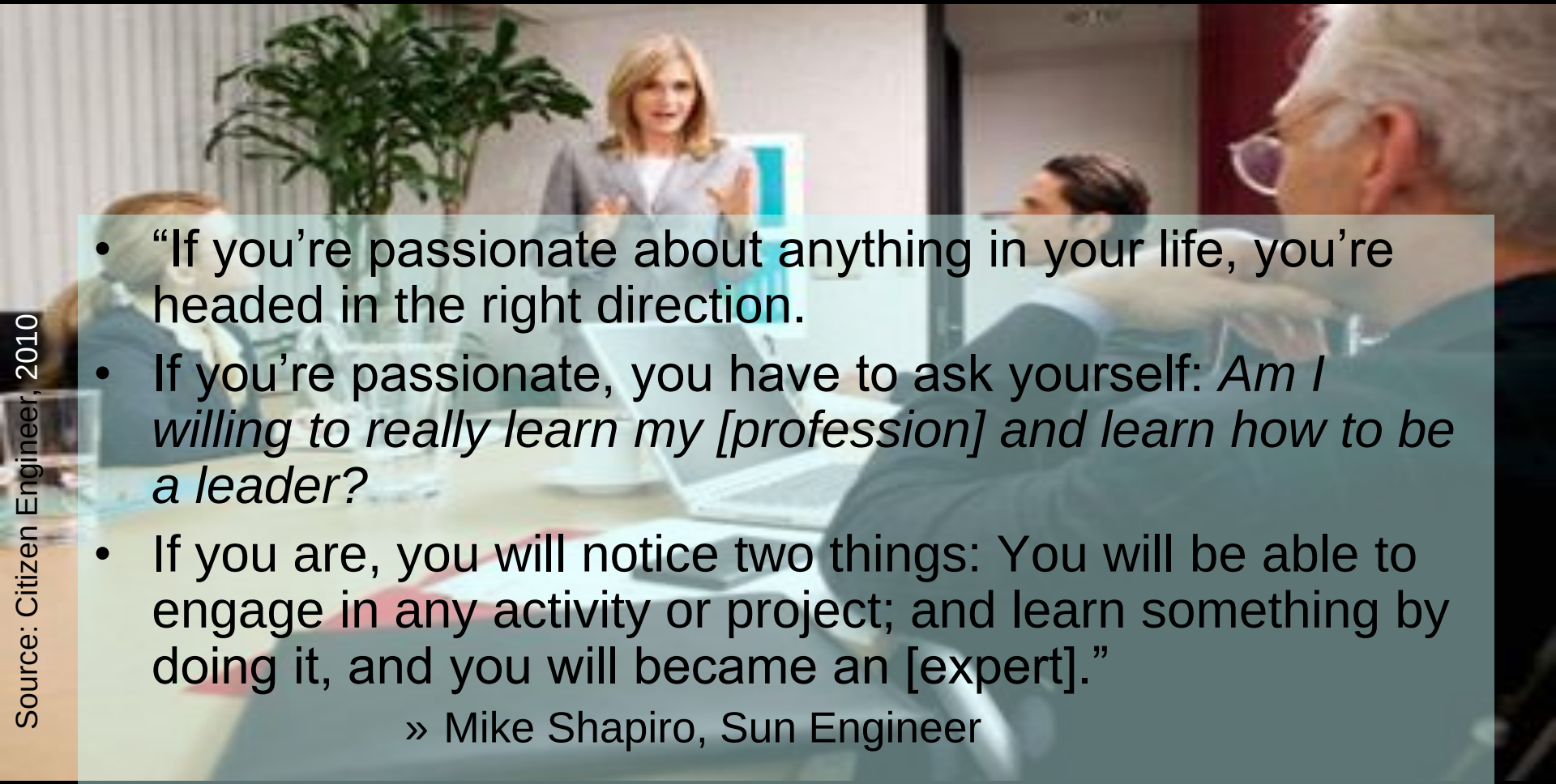
Education of the Citizen Engineer

Education of the Citizen Engineer

- **Participate in the public dialog** – as engineers, you bring skills and gifts to your local and national communities
  - **Analytical reasoning, logical thinking, practical understanding, and engineering know-how**

Source: Citizen Engineer, 2010

Advice for Engineering New Hires



- “If you’re passionate about anything in your life, you’re headed in the right direction.
- If you’re passionate, you have to ask yourself: *Am I willing to really learn my [profession] and learn how to be a leader?*
- If you are, you will notice two things: You will be able to engage in any activity or project; and learn something by doing it, and you will became an [expert].”

» Mike Shapiro, Sun Engineer

Source: Citizen Engineer, 2010

Ethics & Policies

ASCE - Sustainability

- In October 2009, the ASCE Board of Direction adopted the following definition of Sustainable Development: "**Sustainable Development is the process of applying natural, human, and economic resources to enhance the safety, welfare, and quality of life for all of society while maintaining the availability of the remaining natural resources**."

Other Related ASCE Policies

- Policy Statement 360 - Impact of Climate Change
- Policy Statement 488 - Greenhouse Gases
- Policy Statement 517 - Millennium Development Goals

From ASCE Fundamental Canons

Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of **sustainable development** in the performance of their professional duties.

From ASCE CANON 1

- b. Engineers whose professional judgment is overruled under circumstances where the safety, health and welfare of the public are endangered, or the principles of **sustainable development** ignored, shall inform their clients or employers of the possible consequences.
- d. Engineers should seek opportunities to be of constructive service in civic affairs and work for the advancement of the safety, health and well-being of their communities, and the protection of the environment through the practice of **sustainable development**.
- e. Engineers should be committed to improving the environment by adherence to the principles of **sustainable development** so as to enhance the quality of life of the general public.

From ASCE CANON 3

- a. Engineers should endeavor to extend the public knowledge of engineering and **sustainable development**, and shall not participate in the dissemination of untrue, unfair or exaggerated statements regarding engineering.

Examples from Major Global Program

London 2012 Olympics Programme

Olympic Park - Site Features

Master Plan

- 670 acres
- 9 venues at Olympic Park
- 2m m³ earthworks
- 40+ bridges
- 10km road